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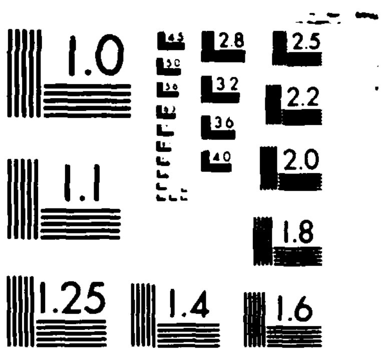

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ANTHROPOMETRIC-ARM RADIOGRAMMETRIC ASSESSMENT OF BODY COMPOSITION, MUSCULARITY AND FRAME SIZE

Annual Report

Frank I. Katch
Albert R. Behnke

August 1, 1980 - May 26, 1981

Supported by

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Preliminary data are presented on a new method for quantifying total body fat based on height, weight, and six fat widths taken from an x-ray of the upper [illegible]. The results include comparisons of subcutaneous fat measured in the standing and lying positions at seven sites by fatfold calipers and a portable ultrasound meter.

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FOREWORD

For the protection of human subjects the investigator(s) have adhered to policies of applicable Federal Law 45CFR46.

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PART 1. EXPERIMENTAL STUDIES

Research Activities: September 1, 1980 to May 26, 1981

Overview.

Because of delays in processing the contract application, the actual x-ray, arm radiographic work did not begin until September 1, 1980. For a period of two months prior to this, however, reliability studies were conducted with ultrasound measurements in 30 females. Both within and between day reliability was established for 7 sites in the lying and standing positions. The results of these analyses are presented in Tables 1, 2, and 3.

In early October of 1980, Dr. Albert Behnke, co-principal investigator, reviewed the basic x-ray procedures and techniques at the University Health Services at the UMass Amherst campus. It was decided to incorporate an additional measurement technique for obtaining the x-ray widths. We refer to this new procedure as bone-axis measurement; it is described on pages 3 and 4.

For a two week period in October, the student research assistants were thoroughly briefed on all aspects of measurement techniques for skinfolds, girths, bone diameters, residual lung volume, and hydrostatic weighing. Practice body composition measurements were made on 15 volunteers, in duplicate or triplicate, until all techniques were well practiced and the basic protocol established.

Individual data sheets, the informed consent document, appointment schedules, and appropriate accounting and a data filing system were established.

For each subject, the following test schedule was followed:

1. Interview, explanation of testing, sign informed consent document;

2. Skinfolds;

3. Circumferences;

4. Diameters;

5. Residual lung volume; duplicate trials;

6. Hydrostatic weighing; 10-12 trials;

7. Ultrasound; within 3 days of hydrostatic weighing; triplicate trials;

8. X-ray; within 5 days of hydrostatic weighing; single x-ray.

Through May 26, 1981, all the anthropometric, hydrostatic weighing, ultrasound, and x-ray measurements were completed for the 100 subjects.

	MEN		WOMEN	
Measure	Age 20-30	Age 30-40	Age 20-30	Age 30-40
Anthropometry	25	25	25	25
Hydrostatic Weighing	25	25	25	25
Ultrasound	25	25	25	25
X-Rays Taken	25	25	25	25
X-Rays Analyzed	25	25	25	25

The only aspect of the research not yet complete is the computer digitizing of each x-ray film with an accompanying individual analysis and report. However, the Graf Pen sonic digitizer has been purchased following a price increase that necessitated an internal budget rearrangement with appropriate approvals) and has been installed. The

digitizer apparatus is operational and the computer software is currently being written and tested.

For the data analysis, the individual records are being transferred to coding sheets for computer entry.

Techniques of Measurement

Measurements were made of skinfolds, girths, bone diameters, hydrostatic weighing and residual volume, x-ray and ultrasound. The exact techniques of measurement for the skinfolds and girths followed guidelines by Behnke and Wilmore (2); for hydrostatic weighing, the methods outlined by Katch et.al. were followed (4), and residual lung volume was measured by O_2 dilution (6).

The following concerns the details of measurement for the x-ray and ultrasound procedures.

X-Ray Procedures. For the upper arm x-ray, the KVP is 120, exposure time is 1/30th of a second, 10 MAS, and focal length is 72 inches. During the x-ray, a vertical rod was used to stabilize the arm. Subjects grasped the rod placed snugly between the two middle fingers of the right hand. The technician raised or lowered the rod until the arm was horizontal.

For the analysis, the x-ray is placed on a suitably illuminated screen and the appropriate width measurements taken with a vernier caliper (Scientific Precision Instruments, Switzerland) and read to the nearest .05 mm. A second technique of measurement referred to as the bone-axis technique is also being compared to the original Behnke-Carlstein technique. In the Behnke-Carlstein procedure, the width measures on the x-ray are drawn perpendicular to the long axis of the humerus, using the horizontal film edge as the reference horizontal

line. In the bone-axis method, the widths are drawn as perpendiculars to a line that bisects the long axis of the humerus. Behnke-Carlstein were concerned that such "slanting" might distort the true width measures. To determine whether or not slanting affects the analysis of the x-ray, a statistical comparison will be made of the Behnke-Carlstein and bone-axis measurements. Duplicate bone-axis measurements have been made for the first 30 x-ray films; thereafter, one such measurement is made. For both techniques, the following measurements have been made at the three arm sites: (1) total width, (2) fat, (3) muscle, (4) bone, (5) marrow, and (6) cortex.

Ultrasound Procedures. This section discusses the operation of the body composition meter (Ithaco, Inc., Ithaca, NY), and the techniques to measure subcutaneous fat thickness at the seven sites.

1. Body composition Meter (BCM). High frequency sound waves (2.5 mHz) are emitted from the transducer head of the BCM and penetrate the skin surface. The sound waves pass through the adipose layer until the muscle layer is reached, where they are then reflected from the fat-muscle interface. This produces an echo that returns to the transmitter which also acts as a receiver. The time it takes from transmission of the sound waves through the tissue and back to the receiver is converted to a distance score and displayed on an LCD readout on the panel meter. The BCM can measure fat to 50 mm thickness (to the nearest one mm) on the lower scale and to 100 mm thickness (to the nearest 2 mm) on the upper scale.

2. Techniques of Ultrasound Measurement. The following sites are measured; they correspond to the same anatomical location defined for the skinfold measurements:

A. Triceps; halfway between acromion and olecranon, in line with the proximal point of the ulna.

B. Biceps; directly in line with the center of the cubital fossa at the same level as the triceps site.

C. Subscapula; 2 cm below the inferior angle of the scapula.

D. Abdomen; 5 cm to the right and at the level of the umbilicus.

E. Iliac; 2 cm medial to the anterior-superior spine.

F. Thigh; anterior and midway between the anterior-superior iliac spine and mid-patella.

G. Calf; medial side, one-third the distance from the medial border of the popliteal angle to the inferior point on the malleolus.

All measurements are taken on the right side of the body with the subject either standing or lying comfortably on a cot. For measurements made in the prone lying position (triceps and subscapula), the arms were kept at the side of the body. The approximate measurement site is cleaned with isopropyl rubbing alcohol and then the exact site of measurement is marked with a felt tip pen. The open end of a disposable cardboard mouthpiece is then inked from an ordinary ink pad. An impression is made around the center of the felt tip dot on the skin surface. As it turns out, the ink impression is the same size as the surface of the transducer head. This makes it very convenient in locating the area for ultrasound measurement. A dab of mineral oil

; applied to the skin surface; this acts as an interface between the ransducer head and skin surface. We have found that a variety of gel reparations are satisfactory.

PART 2. PRELIMINARY RESULTS OF EXPERIMENTAL STUDIES

eliability of Ultrasound Measurements: Standing Position

Table 1 displays the trial-to-trial reliability coefficients for he 7 sites on the 2 days of measurement made in the standing position N=30 females). The last column is the reliability of the mean of 3 rials on Day 1 versus Day 2. A minimum of one day separated the two ests, with no more than 3 days between test and retest. Each measure-ent was taken in this order: biceps, abdomen, iliac, thigh, triceps, ubscapula, and calf. The same sequence of measurement was followed or two additional trials, and for the 3 trials measured on Day 2.

The reliability coefficients for each of the sites within and etween days was significant at $P < .01$. The highest coefficients for Day 1 versus Day 2 were obtained for triceps ($r = .97$) and thigh $r = .96$), followed by subscapular and calf ($r = .90$), biceps $r = .86$), iliac ($r = .83$) and abdomen ($r = .82$).

eliability of Ultrasound Measurements: Lying Position

Table 2 presents the trial-to-trial reliability coefficients within and between the 2 test days for the 7 measurement sites made in the lying position ($N = 30$ females). The same sequence of measurement was used for the lying and standing positions. It should be noted that a balanced order test design was employed in securing all the ultra-sound measurements. This was done to minimize a sequence effect and/or

itematic changes in measurement techniques. Subjects were tested on lays. The test conditions, standing or lying, were systematically :ated on test days as follows: Subject 1: standing, standing, lying, ing. Subject 2: standing, lying, standing, lying, and so on for the naining subjects.

As was the case with the reliability coefficients obtained for e ultrasound measures in the standing position, reliabilities within d between days for the seven sites were all significant at $P < .01$. e highest coefficients for Day 1 versus Day 2 were thigh ($r = .97$) d biceps ($r = .95$), subscapular ($r = .93$), triceps ($r = .91$), and lf ($r = .86$), iliac ($r = .82$) and abdomen ($r = .78$). In comparing e standing and lying positions, the highest day-to-day reliability s achieved for the thigh site ($r = .96$ and $.97$); the lowest :liabilities in terms of the positional effects were for .iac ($r = .83$ and $.82$) and abdomen ($r = .82$ and $.78$).

mparison of Ultrasound Measurements: Standing versus Lying

Table 3 presents the means, standard deviations, and repeated asures ANOVA for trials and days for the 7 ultrasound sites between e standing and lying positions. As can be noted in the last column, ere were no significant F-ratios between the 3 trials for each site both days, and no significant F-ratios between trials or days when mparing the standing and lying ultrasound measurements. What this dicates, in conjunction with the high intra-trial and inter-day liabilities presented in Tables 1 and 2, is the presence of latively stable individual differences and reproducibility of the ven ultrasound measurements. Because there was no positional effect tanding versus lying) or trials effect, it becomes a matter of

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ABLE 8. : Preliminary Results for Arm X-ray and Densitometric Estimate of Body Fat in Young Men

ubject[a]	Age	Ht, cm	Wt, kg	3F	D	D(BMF)	Percent Body Fat Density	3F	D	D(BMF)
on-Ath	24	179.8	82.3	6.42	6.44	6.50	14.8	14.6	14.5	14.4
on-Ath	23	182.9	68.5	5.80	5.89	6.20	9.51	10.8	10.7	10.1
on-Ath	22	168.3	74.9	6.33	6.39	6.43	25.1	23.7	23.4	23.3
'on-Ath	24	165.8	71.6	6.24	6.23	6.38	14.2	16.8	16.8	16.4
Ion-Ath	24	175.6	71.4	6.05	6.12	6.36	13.0	13.8	13.7	13.2
ıth	22	171.8	68.3	5.98	6.13	6.18	12.1	20.9	20.3	20.3
IEAN[b]	23.4	174.5	73.7	6.17	6.21	6.37	15.3	16.0	15.8	15.5

[a] Ath = Athlete; Non-Ath = Non-Athletes

[b] Based on N = 5 without subject Ath

ABLE 7. : Preliminary Results for Arm X-ray and Densitometric Estimates of Body Fat in Young Women

Subject[a]	Age	Ht, cm	Wt, kg	3F	D	D(BMF)	Percent Body Fat Density	3F	D	D(BMF)
Non-Ath	22	164.7	64.9	5.96	5.95	6.11	28.0	32.7	32.8	31.9
Non-Ath	23	160.5	45.8	5.07	5.06	5.09	16.4	18.1	18.1	18.0
Ath	24	155.7	55.4	5.66	5.80	5.79	23.7	31.9	31.2	31.2
Ath	22	176.3	65.8	5.80	5.76	5.58	15.4	20.1	20.2	20.9
Ath	21	163.5	56.1	5.56	5.60	5.58	20.7	26.8	26.7	26.7
Non-Ath	20	164.8	67.7	6.08	6.03	5.63	30.7	29.0	29.2	31.3
Non-Ath	19	158.4	49.5	5.30	5.33	4.97	22.3	25.0	24.9	26.7
Ath	19	165.4	61.3	5.77	5.8	5.77	20.4	29.1	28.8	29.1
Non-Ath	19	169.1	57.7	5.54	5.56	5.54	18.7	21.2	21.1	21.2
Non-Ath	20	161.5	55.0	5.54	5.55	5.07	13.3	16.4	16.4	18.0
Ath	28	171.7	63.3	5.76	5.79	5.84	25.5	30.4	30.2	30.0
Non-Ath	21	159.7	54.2	5.53	5.55	5.20	20.8	20.8	20.7	22.1
Non-Ath	20	169.4	56.3	5.47	5.45	5.04	20.2	19.8	19.9	21.5
Non-Ath	22	159.1	42.5	4.90	4.82	4.23	12.8	18.5	18.8	21.4
Non-Ath	19	157.5	49.9	5.34	5.38	5.14	22.2	24.4	24.3	25.4
Non-Ath	29	171.5	76.7	6.34	6.20	7.06	28.2	34.0	34.8	30.6
MEAN	21.1	164.3	57.6	5.60	5.60	5.48	21.0	24.9	24.9	25.4

[a] Ath = Athlete; Non-Ath = Non-Athlete

TABLE 6. : Intercorrelations between fatfolds and ultrasound (lying and standing) for 30 females.

	Skinfolds vs. Ultrasound (Lying)	Skinfolds vs. Ultrasound (Standing)	Ultrasound vs. Ultrasound (Standing)	t-ratio[b]
Triceps	.907[a]	.860	.969	2.365[c]
Scapula	.576	.511	.894	0.397
Iliac	.868	.861	.948	0.219
Abdomen	.650	.612	.970	1.023
Thigh	.954	.952	.983	0.010
Calf	.893	.915	.973	1.193
Biceps	.794	.780	.922	2.210[c]

[a] $r = .463$ is required for significance at $P < .01$.

[b] Hotelling t-ratio for determining the significance of the difference between correlations (skinfolds versus ultrasound lying and standing) in the same subjects.

[c] $p < .05$; $t = 2.052$ is required for significance at the .05 level for $df = N-3$.

TABLE 5. : Ratio of Corrected Skinfolds[a] to Ultrasound in the Standing and Lying Positions (N = 30 Females)

Site	Corrected Skinfold	Ultrasound Mean	(Standing) Ratio	Ultrasound Mean	(Lying) Ratio	Ratio Average[b]
Triceps	18.36	14.43	1.275[c]	14.61	1.257	1.266
Scapula	12.58	6.79	1.853	6.78	1.855	1.854
Iliac	12.60	11.87	1.061	11.64	1.082	1.072
Abdomen	17.41	12.93	1.346	13.29	1.310	1.328
Thigh	23.70	14.33	1.654	13.49	1.757	1.706
Calf	16.31	13.24	1.232	11.89	1.372	1.302
Biceps	9.47	8.61	1.100	7.85	1.206	1.153

[a] Corrected skinfold value refers to the observed mean skinfold value minus 0.9 mm reported by Tanner(5) for a single layer of skin thickness

[b] Ratio average based on ratios for ultrasound (standing and lying).

[c] Interpret the ratio of 1.275 to mean that the corrected triceps is 1.275 times larger than the corresponding ultrasound skinfold measurement (standing).

TABLE 4 : Mean and Standard Deviation of Skinfolds Compared with Ultrasound in the Standing and Lying Positions (N = 30 Females)

Site	Skinfold[a] Mean	SD	Ultrasound (Standing) Mean	SD	Ultrasound (Lying) Mean	SD
Triceps	19.26	5.21	14.43	4.64	14.61	4.21
Scapula	13.48	3.96	6.79	2.22	6.78	2.38
Iliac	13.50	5.01	11.87	3.63	11.64	4.16
Abdomen	18.31	6.91	12.93	4.91	13.29	5.17
Thigh	24.60	7.48	14.33	4.60	13.49	3.80
Calf	17.21	5.13	13.24	4.43	11.89	3.35
Biceps	10.37	3.62	8.61	3.62	7.85	3.26

[a] Double skin thickness

TABLE 3 : Means, Standard Deviations, and ANOVA for Ultrasound Measurements for Three Trials Taken on Successive Days (N = 30 Females)

		DAY 1				DAY 2			
SITE	CONDITION[a]	T_1	T_2	T_3	Ave_1	T_1	T_2	T_3	Ave_2
Triceps	S	14.13 5.08	14.37 4.91	14.33 4.51	14.29 4.75	14.67 4.65	14.57 4.50	14.50 4.86	14.58 4.59
	L	14.40 4.54	14.43 4.16	14.57 4.30	14.47 4.30	14.87 4.23	14.67 4.40	14.70 4.41	14.74 4.32
Scapula	S	7.03 2.63	6.53 2.52	6.80 2.46	6.79 2.39	6.93 2.33	6.90 2.31	6.57 2.21	6.80 2.15
	L	6.60 2.74	6.70 2.67	6.70 2.52	6.67 2.58	6.93 2.15	6.93 2.24	6.83 2.57	6.90 2.27
Iliac	S	11.37 4.25	11.47 4.66	11.90 4.37	11.58 4.25	12.23 3.65	11.97 3.09	12.27 3.49	12.16 3.34
	L	11.47 4.79	11.90 5.20	11.50 4.85	11.62 4.89	11.57 3.72	11.70 4.00	11.70 3.91	11.66 3.82
Abdomen	S	13.03 5.88	13.30 5.67	13.70 6.57	13.34 5.81	12.60 4.67	12.57 4.75	12.40 4.41	12.52 4.46
	L	13.90 6.56	13.77 6.54	13.80 6.35	13.82 6.48	12.77 4.35	12.90 4.74	12.63 4.54	12.77 4.46
Thigh	S	14.03 4.49	14.33 4.62	14.00 4.89	14.12 4.57	14.37 4.70	14.53 4.58	14.73 5.18	14.54 4.71
	L	13.03 4.31	13.43 4.07	13.50 3.88	13.32 3.98	13.53 3.75	13.70 3.56	13.77 3.79	13.67 3.68
Calf	S	13.10 4.53	13.33 4.57	12.90 4.71	13.11 4.46	13.63 4.89	13.27 4.51	13.20 4.64	13.37 4.64
	L	11.67 3.38	11.70 3.45	11.80 3.53	11.72 3.40	12.07 3.52	12.03 3.59	12.07 3.58	12.06 3.55
Biceps	S	8.50 4.05	8.90 3.80	8.77 4.34	8.72 3.89	8.20 3.42	8.60 3.62	8.67 3.92	8.49 3.62
	L	7.70 3.41	7.83 3.54	7.93 3.35	7.82 3.40	7.83 3.45	7.97 3.19	7.83 3.16	7.88 3.21

Values are means plus or minus standard deviations.
[a]S = standing; L = lying.
[b]F statistic computed for repeated measures ANOVA (trials versus days) for N = 30. All comparisons were non-significant at P > .05.

TABLE 2 : Trial to Trial Reliability[a] for Seven Sites Measured on Two Days for Ultrasound in the Lying Position (N = 30 Females).

Site	Day 1			Day 2			Day 1 vs Day 2[b]
	T1-T2	T1-T3	T2-T3	T1-T2	T1-T3	T2-T3	
Biceps	.96[c]	.97	.98	.93	.93	.95	.95
Abdomen	.99	.99	.99	.96	.92	.96	.78
Iliac	.95	.99	.96	.98	.95	.94	.82
Thigh	.89	.89	.98	.98	.98	.98	.97
Triceps	.97	.98	.98	.98	.98	.99	.91
Subscapular	.93	.91	.95	.94	.92	.92	.93
Calf	.96	.97	.95	.98	.98	.99	.86

[a] T_1 = Trial 1; T_2 = Trial 2; T_3 = Trial 3.

[b] Mean of 3 trials on Day 1 versus mean of 3 trials on Day 2.

[c] $r = .46$ is required for significance at $P < .01$.

TABLE 1 : Trial to Trial Reliability on Two Days for Ultrasound in the Standing Position (N = 30 Females).

Site	Day 1 T1-T2	Day 1 T1-T3	Day 1 T2-T3	Day 2 T1-T2	Day 2 T1-T3	Day 2 T2-T3	Day 1 vs Day 2[b]
Biceps	.85[c]	.86	.92	.97	.97	.98	.86
Abdomen	.93	.85	.87	.88	.98	.86	.82
Iliac	.84	.94	.88	.92	.93	.97	.83
Thigh	.96	.94	.92	.96	.91	.93	.96
Triceps	.93	.95	.97	.94	.96	.96	.97
Subscapular	.80	.79	.92	.81	.76	.93	.90
Calf	.91	.95	.87	.97	.97	.98	.90

[a] T_1 = Trial 1; T_2 = Trial 2; T_3 = Trial 3.

[b] Mean of 3 trials on Day 1 versus mean of 3 trials on Day 2.

[c] r = .46 is required for significance at P < .01.

offer a new dimension to body composition assessment.

3. Based on preliminary analysis, the new arm x-ray method to calculate body fat appears to be valid for so called "normal" individuals who do not participate regularly in physical exercise programs, and who are within the generally accepted range of body fat percentage.

It must be noted however, that the conversion constants originally developed on a heterogeneous group of tunnel workers requires revision for more precise quantification of body composition. The constants do not appear to be universal in nature, but dependent on age, sex, fitness category, and body size. The major objective of the renewal proposal is to secure these data.

Once the appropriate constants are developed for a reference sample of males and females who vary in body composition and fitness status, a highly valid method will be available for rapid computer analysis of body composition and nutritional status. This should provide a more reliable and valid method to determine the relative amount of body fat in the body, as well as bone-muscle in the arm referred to lean body weight. A permanent record of arm tissue will enable intra- and inter-individual comparisons during studies of metabolism and physiological function, especially where lean body weight can be used as a suitable reference baseline.

of 16-17% between percent fat (density) and percent fat based on 3F and D (24.9%), and BMF (25.4%).

The very encouraging results are the validity correlations between percent fat (density) and the 3 x-ray methods of estimating body fat. The correlations are r = .860 between percent fat (density) and percent fat (3F, x-ray), r = .866 between percent fat (density) and percent fat (D, x-ray), and r = .874 between percent fat (density) and percent fat (BMF, x-ray). Of course, these data are very tentative but suggest strongly that discrepancies are caused by the non-universality of the conversion constants. This assertion is further illustrated in Table 8 that displays the results for 6 young men, one of whom was a weight-lifter who had also e durance trained for th past year by running 60-70 miles a week. The agreement between density and the 3 x-ray estimates of body fat for the other 5 men was nearly identical (15.3% versus 16.0%, 15.8% and 15.5%, respectively for the 3F, D and BMF conversions). For a 39 year-old man (not endurance trained, not listed in the table), percent fat (density) was 25.6%; it was 24.0% (3F), 24.6% (D) and 24.3% (BMF).

<u>Summary of Preliminary Studies for 16 Women and 6 Men</u>

Based on the preliminary analysis for the ultrasound and x-ray analysis, we conclude the following:

1. The ultrasound technique is a reliable method for determining individual differences in subcutaneous fat thickness in females independent of body position (lying or standing).

2. The relatively high intercorrelations between skinfold and ultrasound measurements is very encouraging and appears to

constant 5.29. The latter was derived from the mean values of the respective dimensions in the Behnke-Carlstein survey of 30 male tunnel workers, divided by the mean value of D (6.54). The D score is the sum of 11 girth measures divided by 100. The 3F and D values usually yield comparable values.

(3) % Fat = Fat, x-ray/ D x .0471, where D is the sum of 11 girths and .0471 is a constant.

The truly remarkable results of the Behnke-Carlstein study was the very close agreement between the different conversions of radiographic fat, muscle, and bone widths to percentage of body fat. What was lacking in their novel investigations was a critical validation of arm radiogrammetric estimates of body fat by an established independent method such as densitometry. Furthermore, the constants used in the conversions were derived from a rather unique sample of male tunnel workers. As will be shown subsequently in the x-ray analysis for young females, some of whom are athletes, as well as for several athletic young men, the original conversion constants used to compute percent body fat are inadequate for precise estimations.

1. X-ray-arm radiographic analysis of young women (N=16) and men (N=6)

Tables 7 and 8 present preliminary analysis for 16 women and six men for the arm x-ray and densitometric estimates of body fat. Included in these groups were athletes and non-athletes. What is apparent is the discrepancy between percent fat (density) and percent fat (x-ray, 3F, D, D(BMF)) for the athletes and one female with a low percentage of body fat. There is very close agreement between the 3 x-ray methods of calculating body fat, but a difference

ficance of the difference between the correlations for ultrasound (standing and lying) and skinfolds. These values are listed in the last column and reveal that the correlations between ultrasound and skinfolds for the triceps and biceps were significantly different at $P < .05$. The intercorrelations between ultrasound measures lying and standing ranged between $r = .89$ for the scapula to $r = .983$ for the thigh. The highest correlation was obtained for the thigh site, not only for the comparison between lying and standing, but between the ultrasound measures and skinfolds.

Preliminary Results of X-Ray Analysis

The basic objective of the arm x-ray procedure is to convert fat and muscle plus bone x-ray widths into individual estimates of body fatness and lean body weight. The original arm radiogrammetric analysis was made on a sample of 50 male compressed air tunnel workers who ranged in age from 21 to 65 years, in stature from 166 to 207 cm, and in body weight from 58 10 136 kg. Arm radiographs were also taken of 3 females; a young girl of 12 years, her mother, and an obese, middle aged secretary. Except in two cases, body density by underwater weighing was unavailable, but percent body fat and lean weight could be calculated from stature and bone diameter measures. With this baseline information, the basic theoretical constants employed in the conversion of radiogrammetric widths to body fat were formulated.

(1) % Fat = Fat, x-ray/ 3F x .0471, where 3F is

3 x wt., kg/ht, dm, and .0471 is a constant.

(2) % Fat = Fat, x-ray/ D(BMF) x .0471, where D(BMF) is the bone, muscle and fat x-ray widths divided by the

investigator preference to select the manner in which the measurements are made.

We recommend that for research purposes, the lying position be used because of the relative ease with which measurements can be taken. However, the standing position will give comparable results and may be preferable in field testing situations. A minimum of 2 trials should be taken, in rotational order and then averaged, although the average of 3 or more trials would theoretically increase the precision of estimating an individual's "true" ultrasound measurement of subcutaneous fat at a given site.

Comparison Between Skinfolds and Ultrasound

Table 4 presents the means and standard deviations for the skinfold and ultrasound measurements. Each skinfold thickness was larger than the corresponding ultrasound measure of subcutaneous fat. To determine the magnitude of the difference, the ratio skinfold/ultrasound was computed for each measurement site and is displayed in Table 5. The corrected skinfold value refers to the observed mean value minus 0.09 mm, the thickness for a single layer of skin. The last column contains the average of the ratios for ultrasound (standing and lying). The corrected iliac skinfold and iliac ultrasound measures were close; the former being only 1.072 times as large. The largest difference occurred between the scapula measures; the ratio was 1.854, which means this skinfold was nearly double in thickness compared to ultrasound.

Table 6 presents the intercorrelations between skinfolds and ultrasound (lying and standing). All the correlations were significant at $P < .05$. The Hotelling t-ratio was computed to determine the signi-

APPENDIX I

Informed Consent Document

ANTHROPOMETRIC-ARM RADIOGRAMMETRIC ASSESSMENT OF BODY FATNESS, MUSCULARITY AND SKELETAL FRAME SIZE

INFORMED CONSENT DOCUMENT-- BODY COMPOSITION PROJECT/RENEWAL

Your written consent is required before you can participate in the Body Composition Project. Please read this document carefully and then sign your name in the space provided. The following guidelines are established in accord with the Code of Federal Regulations 45, Public Welfare, Part 46, Protection of Human Subjects, and with legal requirements applicable to the University of Massachusetts. These guidelines supercede those contained in Senate Document 72-061 and became effective on September 1, 1978. In accord with the Code of Federal Regulations as described immediately above, and as amended November 3, 1978 by Federal Register Document 78-30752 Interim Final Regulation, and in accord with the directive of the Office of Protection from Research Risks of the NIH following policy amendments by the University of Massachusetts/Amherst General Assurance G0147XM, the following policy amendments by the University Human Subjects Review Committee were adopted on February 15, 1979.

PURPOSE: To develop a simple, reliable and valid method of body composition evaluation.

PROCEDURES:

1. Your height and weight will be measured.

2. Twelve circumference measurements will be taken with a cloth tape. The sites include: neck, shoulders, chest, hips, abdomen, thighs, knees, calfs, ankles, wrists, forearms, biceps.

3. Eight bone measurements will be taken with a wooden caliper. The sites include: shoulders, chest, hips, ankles, knees, wrists, elbows.

4. Five surface fat measurements will be taken with a skinfold caliper. The sites include: back of arm, shoulder blades, hip, abdomen, mid-thigh.

5. Ultra-sound measurements for fat determination will be taken at seven sites: back of the arm, biceps, shoulder blades, hip, abdomen, mid-thigh, and calf.

6. Your body volume will be measured by a water immersion test. You will be seated in a chair suspended in a water tank. You will exhale your air and submerge. You will hold your breath for 3 seconds while submerged in a bent-

forward position. This procedure will be repeated 10 times with ample time between. The chair is balanced so your sitting position is maintained throughout the test.

7. You may use a snorkel if you wish. A nose clip and ear plugs can also be worn. You may raise your face out of the water at any time. The procedure is similar to sitting in a bath tub with the water level up to your neck. You then lean forward to submerge your head while you are weighed submerged.

8. We will also measure the volume of your lungs. This is done before the water test. You will sit in a chair and breathe into the lung machine (spirometer) for 6 to 8 normal breaths. A nose clip is worn. The procedure takes about 15 seconds, and is repeated twice. The lung score is needed in the calculation of body composition.

9. An x-ray will be taken of your right upper arm (between your elbow and shoulder). This will be done in the x-ray department of the University Health Services by a licensed x-ray technician. The x-ray dosage is 10 mR (milliroentgens), which is the same dosage as a standard x-ray. As a frame of comparison, the x-ray mR exposure is 200 for a back x-ray, 23 mR for a foot x-ray, and 150mR for an abdominal x-ray. The average x-ray exposure from non-occupational sources (environment) is 100 mR per year at sea level.

DISCOMFORT OR RISKS:

1. There are no discomforts or risks with the various body composition tests. In very rare cases, subjects may swallow a small amount of water if they inhale instead of exhale during water submersion.

2. There may be some as yet unknown long term effects of exposure to x-ray; there is no scientific evidence that a 10mR exposure equivalent to a standard chest x-ray poses any short-term or long-term harmful effects to humans.

BENEFITS:

1. Participation in a scientific research study.

2. Contribution to the advancement of science in the field of human body composition research with immediate practical application to the allied medical professions.

3. Renumeration of 15 dollars for completion of all testing.

4. Knowledge of your results about the various tests.

ALTERNATIVE PROCEDURES:

1. The current techniques are commonly in use throughout the world, both in children and adults of both sexes.

2. Alternative procedures were not considered as they are complex and invasive (isotopic dilution) and impractical (potassium counting and neutron activation).

QUESTION AND ANSWERS:

1. All questions concerning any of the procedures will be answered before or after testing.

WITHDRAWAL:

1. You are free to withdraw consent and discontinue participation at any time during testing, without penalty or loss of benefits to which you are otherwise entitled.

CONFIDENTIALITY:

1. All data obtained will be kept confidential. You will not be identified by name or any other means in any summaries, publications, or reports that result from the research.

In addition to the items discussed in this document, the principal investigator (Dr. Frank Katch) will conduct all procedures with consideration of your best interests and to insure your safety and comfort. Dr. Katch serves as the contact person for all information pertaining to the project.

Frank I. Katch, Principal Investigator
Chairman, Department of Exercise Science
University of Massachusetts, Amherst, MA 01003
Telephone: (413) 545-1337

I have read and understood the Informed Consent Document as described and give my consent for participation in the Body Composition Project.

Date:________________________

Signed:________________________

Address:________________________

____

Telephone:________________________

University Health Service Clearance to participate:

yes__________ no____________

Physician:____________________

Date:________________________

NOTE

Persons should not be tested who have had previous x-ray exposure of the following type:

1. Fluoroscopy
2. Back x-rays
3. Mammography
4. IVP
5. Skull x-rays
6. Other diagnostic x-rays in large amounts
7. Pregnant women or any woman who feels she might possibly be pregnant

Any subject who has a current ear infection, sinus infection, skin condition, or phobic reaction to being submerged under water should not be tested.

END

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